# Final Technical Report for NASA Grant NAG 5-1678

## HRI Observations of Powerful Radio Galaxies
## Positional Confirmation of Optically Quiet Quasars

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This grant funded two HRI projects related to studies of active galactic nuclei under the *ROSAT* Guest Observer Program. One study produced complimentary data confirming that nature of candidate 'Optically Quiet Quasars' as part of a paper published in the *Astrophysical Journal.* The second study produced some ambigious results on the cluster environment of radio galaxies which and have been folded into an other ongoing study to produce a larger sample. Grant funds for both of these efforts have been expended.

Our work on 'Optically Quiet Quasars' has appeared in the Astrophysical Journal, with summaries presented at two conferences. Optically Quiet Quasars (also called 'Red Quasars') are X-ray emitting radio-loud AGN with relatively weak optical emission. Astrophysical explanations for this atypical spectral energy distribution range from intrinsically unusual output from the central engine, to absorption of the optical and soft X-ray emission either near the central engine or from an unrelated system along the line of sight. One objective of this study was to identify and make followup observations of 10 candidate OQQs. Six of these candidates were identified in the southern hemisphere using a combination of the *ROSAT* all sky survey, COSMOS plate scans, and radio sources in both the Mologolo Reference Catalog and Parkes-MIT-NRAO surveys. Six candidate OQQs were identified in this manner. Followup higher resolution radio observations of these AGN made with the ATCA are reported in Kollgaard et al (1995).

The HRI observations covered in this grant were complimentary to these data on the southern OQQ candidates yielding X-ray positions of comparable accuracy with the ATCA radio positions, as well as X-ray fluxes to verify the original *ROSAT* all-sky survey fluxes. The followup observations found that one of the six southern sources was not a single AGN but a confused field of a few radio and X-ray objects. This is in keeping with statistical estimates for the ocurrence of spurious sources. None of the five other southern OQQ candidates was found to have all of the properties expected of an OQQ, generally because the radio emission from the core was fainter than expected from the original correlation with the MRC and PMN catalogs. The HRI observations confirmed these findings. The more accurate positions obtained with the HRI were within a few arcseconds of the ATCA positions, with the exeption of the spurious source in the confused radio field, confirming that we had indeed located the correct AGN responsible for the X-ray emission. Determining X-ray fluxes with the HRI is complicated by the lack of spectral information. However, using conservative estimates for $N_H$ we were the HRI fluxes are within 50% of the original RASS measurements. In only one case was the HRI flux higher than the RASS estimate. Uncertanties in both the HRI and RASS fluxes, however, make it difficult to ascribe these differences to variability, they may be due to systematic errors. In no instance, however, do the new HRI fluxes alter the conclusion that none of the southern candidates are true OQQs, indeed they further confirm the finding of Kollgaard et al. (1995) that these are not true OQQs.

The second portion of this grant covered the analysis of HRI observations of the gaseous environment around powerful radio galaxies. A number of studies of radio galaxies and BL Lacertae objects, a much rarer class of highly variable AGN, have lead to 'unfied schemes' postulating that BL Lacs are intrinsically identical to low luminosity (Fanaroff-Riley Class I) radio galaxies but with relativistic jets oriented close to the line of sight. Unified schemes

can account for the observational distinctions between BL Lacs and radio galaxies, although details remain unclear. In particular it is unclear if all FR I galaxies are potential BL Lacs. One way to test this idea is to compare the number of BL Lacs and galaxies seen in clusters and look for differences in their cluster environment. Evidence has been cited which both supports and rejects the contention that BL Lacs avoid risch cluster environments. If this is correct then it implies that not all FR I galaxies are potential BL Lacs. This has implications both on the estimates of jet parameters derived from number density counts as well as the physical conditions in the jets which allow them to be supressed in rich gaseous environments.

To facilitate this comparison we have made HRI observations of eight radio galaxies in order to separate the contribution of any cluster emission from the AGN itself. We have found clear evidence for diffuse X-ray emission in three of these galaxies. There are also indications of a diffuse contribution around the FR II galaxy 3C 382 based on our detailed analysis of the radial profile of the X-ray emission (see Figure 1). However, a clear determination of the physical parameters of the diffuse emission surrounding this AGN are complicated by the poor spectral resolution of the HRI and the presence of a diffuse halo in the HRI's point spread function, both of which complicate our deconvolution. The X-ray spectral parameters for the AGN emission from these galaxies are listed in Table 1.

To test the predictions of unified schemes on the nature of cluster environment of BL Lac objects, we have begun comparing the results of our galaxy observations with similiar HRI observations we have made of two nearby BL Lacs (0548-322, 3C 371) known to be in rich cluster environments. Our results thus far are consistent with the expectations of unified schemes, but are hampered by the small number of BL Lacs with detailed HRI observations. We have therefore deferred publication of these data and joined in an effort by E. Perlman and associates to obtain new HRI images of 5 additional BL Lacs which, when combined with our sources and other observations, will result in a sample of 11 nearby BL Lacs with high resolution X-ray observations. After these new HRI data are analyzed we intend to publish a detailed study comparing the X-ray environments of BL Lacs and FR Is within the context of unified schemes.

## References

Kollgaard, R. I., Feigelson, E. D., Laurent-Muehleisen, S. A., Spinrad, H., Dey, A. & Brinkmann, W., *A Search for Optically Quiet Quasars* 1995, ApJ, 449, 61

Kollgaard, R. I., Laurent-Muehleisen, S. A., Feigelson, E. D., Spinrad, H. & Brinkmann, W., *Multifrequency Studies of Optically Quiet Quasars* 1994, The Soft X-ray Cosmos, ROSAT Science Symposium (eds., E. M. Schlegel & R. Petre) p. 423

**Table 1: HRI Radio Galaxies**

Source Parameters

| Source | $z$ | Counts | Rate $\times 10^{-3}$ (ct/sec) | $\log N_H$ | Flux $\times 10^{-13}$ ($cm^{-2}$) | $\log L_x$ (W $Hz^{-1}$) |
|---|---|---|---|---|---|---|
| 3C 66B | 0.0215 | 77 ± 9 | 7.5 | 20.9 | 11.9 | 17.0 |
| 0548-317 | 0.04 | 13 ± 4 | 1.6 | 20.3 | 1.6 | 16.7 |
| 0708+32 | 0.0672 | 554 ± 24 | 22.9 | 20.9 | 36.3 | 18.5 |
| | | 2583 ± 79 | 107. | | 170. | 19.2 |
| 3C 192 | 0.0599 | <8 | <0.5 | 20.6 | <0.6 | <16.6 |
| 1144+35 | 0.063 | 58 ± 8 | 19.1 | 20.3 | 18.7 | 18.2 |
| 3C 293 | 0.0450 | 11 ± 4 | 1.4 | 20.1 | 1.3 | 16.7 |
| 1553+24 | 0.0426 | 12 ± 4 | 1.2 | 20.6 | 1.4 | 19.7 |
| 3C 382 | 0.0578 | 2558 ± 53 | 513. | 20.9 | 814. | 19.7 |
| | | 3117 ± 61 | 625. | | 992. | 19.8 |

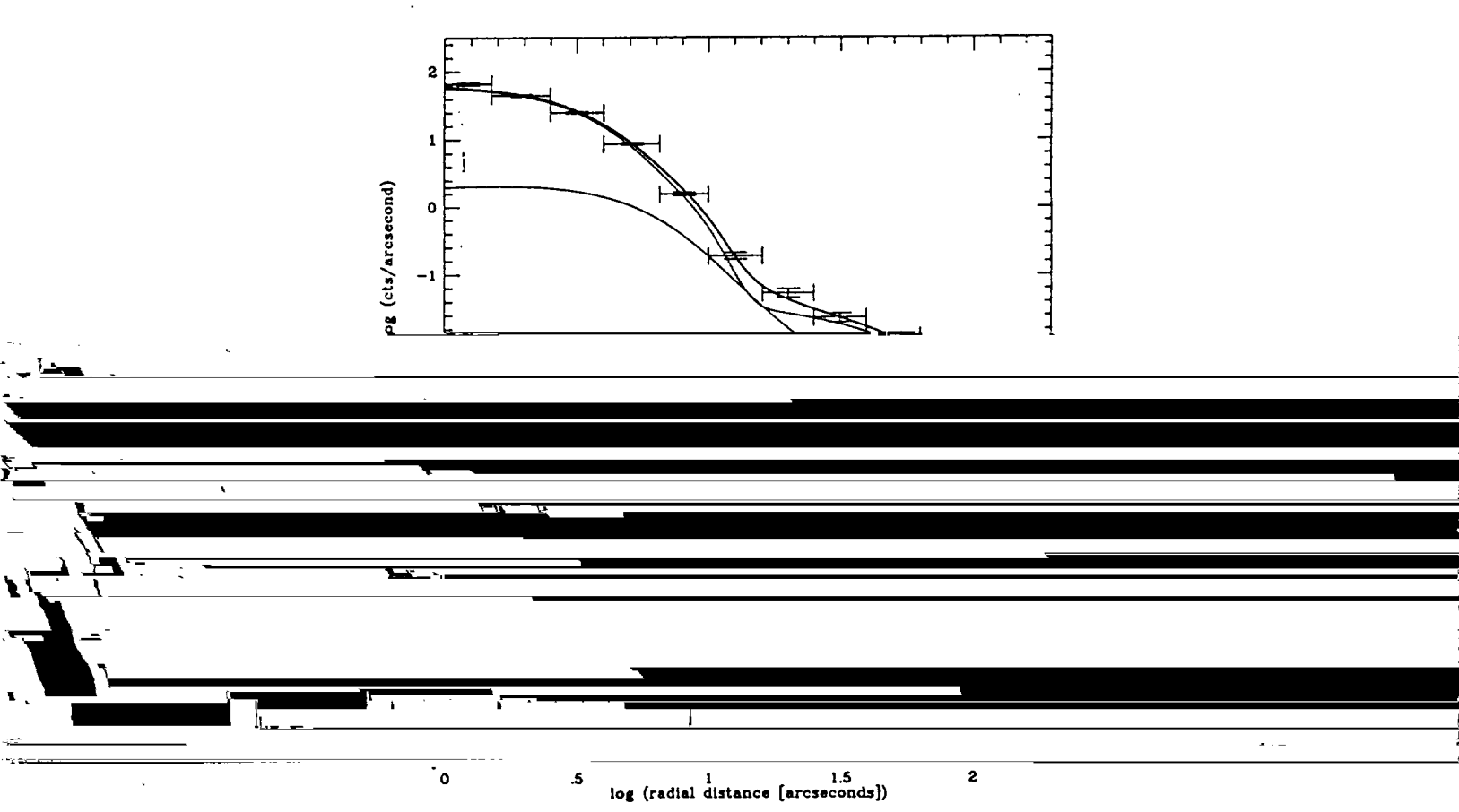


Figure 1: The radial profile of the X-ray emission of 3C 382. A $\beta$-model with a core radius of 3″ and $\beta = 0.66$ is convolved with the HRI point spread function (lower thin line) and added to an unresolved component (upper thin line) to produce a total profile (thick line). This convolution of a point source and diffuse component provides a better fit to the data